J. Raptor Res. 38(4):312–319

DECREASES IN A POPULATION OF RED-SHOULDERED HAWKS NESTING IN CENTRAL MARYLAND

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Abstract.—I report the results of a 32-yr (1971–2002) nesting study of the Red-shouldered Hawk (*Buteo lineatus*) in central Maryland that adds 31 yr of observations to an earlier long-term study. Regression analysis indicated that from 1975–2002 the number of nesting pairs in the study area decreased by at least 78%. An estimate of the population change based on the number of successful nests (fledging at least one young) indicated a decrease of about 88%. The number of young fledged/successful nest decreased slightly. Modest downward trends in the numbers of Red-shouldered Hawks observed during the local Christmas Bird Counts since 1972 provide further evidence of a population in decline. These long-term trends in this nesting population's size and nesting success were contrary to patterns expected as the density of hawks decreased. Human activities resulting, both directly and indirectly, in habitat changes detrimental to this species were likely the principal reasons for these local decreases; similar to declines observed in other Red-shouldered Hawk populations.

Key Words: *Red-shouldered Hawk;* Buteo lineatus; *central Maryland; breeding success; population decline.*

DISMINUCIONES EN UNA POBLACIÓN NIDIFICANTE DE *BUTEO LINEATUS* EN EL CENTRO DE MARYLAND

Resumen.—En este trabajo documento los resultados de un estudio de 32 años de duración (1971–2002)sobre la nidificación de *Buteo lineatus* en el centro de Maryland, añadiendo 31 años de observaciones a un estudio previo de largo plazo. Análisis de regresión indicaron que el número de parejas nidificantes en el área de estudio disminuyó por lo menos en un 78% entre 1975 y 2002. Otro estimado del cambio poblacional basado en el número de nidos exitosos (con al menos un pichón emplumado) indicó una disminución de alrededor del 88%. El número de pichones emplumados por nido exitoso disminuyó ligeramente. Las tendencias moderadas de disminución en el número de *B. lineatus* observados durante los conteos navideños desde 1972 proveen evidencia adicional de que la población está en disminución. Estas tendencias de largo plazo en el tamaño de esta población nidificante y en su éxito de nidificación fueron contrarias a los patrones esperados con la disminución de la densidad poblacional. Las actividades humanas que llevan directa o indirectamente a cambios nocivos en el hábitat para esta especie fueron probablemente las razones principales que explican estas disminuciones locales, de forma similar a las disminuciones observadas en otras poblaciones de *B. lineatus*.

[Traducción del equipo editorial]

In the spring of 1947, U.S. Fish and Wildlife Service biologist Robert Stewart (1949) led a nesting study of the Red-shouldered Hawk (*Buteo lineatus*) in the Patuxent River watershed in parts of Prince George's and Anne Arundel counties, MD covering the coastal plain from Laurel and Fort Meade to tidewater. That study, which included records dating back to 1943, reported a variety of information on the Red-shouldered Hawk (hereafter RSHA) including habitat requirements, population densities, reproductive performance, and food habits. From 1960 through 1967 Fred Schmid, another biologist at the Patuxent Wildlife Research Center (PWRC), located nests and banded nestlings in the heart of Stewart's study area. His observations are included in Henny et al. (1973). In late 1970, a group of biologists led by Charles Henny designed a follow-up study on a portion of Stewart's original area to determine this species' status, a study centered on but not limited to the PWRC. I, with many volunteers, have continued to monitor this RSHA population to provide a continuous 32-yr record using the same methods to extend earlier observations. Because many birds and other species are known to decline in abundance as their habitat patches decrease in size and quality, such

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long-term monitoring is especially useful in this area of growing urbanization as the PWRC area becomes an increasingly isolated large patch of forest. Henny et al. (1973) noted that the PWRC remained an atypical "island of remaining habitat," where the RSHA population still seemed to be doing well at a time when many other populations of this species were declining. Bednarz and Dinsmore (1981) cited 14 references indicating that the RSHA population had declined in Iowa and elsewhere and was listed as rare or endangered in five states, probably largely due, directly or indirectly, to habitat change. These authors stated that "Timber harvesting (selective or clear-cutting), dam construction, and channelization all have major detrimental impacts on natural bottomland communities. Clearly, the Red-shouldered Hawk will continue to decline as river systems and lowland habitats continue to be modified and developed" citing several additional references to support this prediction. Titus et al. (1989) reported that five northeastern states had listed the RSHA as either "threatened," of "special concern," or a candidate for listing.

Data reported here supplement the earlier population data for central Maryland and enable me to test the hypothesis that the PWRC is still an island of prime RSHA habitat. I will thus examine the size and breeding success of the RSHA population on and around this area to learn if changes have occurred therein since the early 1970s and suggest possible causes for any changes.

STUDY AREA AND METHODS

The study area, as described by Henny et al. (1973), included a mostly mature woodland in the floodplain and adjacent upland along the Patuxent River from Laurel (39°06′07″N, 76°50′22″W) downstream to Bowie State University (39°02′04″N, 76°45′06″W). Since 1972, I have continued to cover this same area plus a 23% extension downstream to the old Bowie Race Track (39°00′36″N, 76°44′11″W), a total of about 1077 ha. Henny et al. (1973) also provided a detailed description of their methods and a thorough analysis of the population data available for the PWRC segment for the 29-yr period 1943–71. Even more detailed information on the area's physical characteristics together with annotated lists of much of the flora (Hotchkiss and Stewart 1947) and fauna of the PWRC were published in one booklet (Anonymous 1979). Following the methods of Henny et al. (1973), the study area was searched on foot from early March through May each year for any evidence of RSHA nesting ranging from courtship and nest building through fledging. Total nests found showing evidence of use by nesting RSHA (e.g., presence of an adult, fresh leafy material or down on the nest, droppings indicative of young in the nest, and young seen in the nest) provided an index of population size each season. Any such nest from which at least one young most likely fledged (usually indicated by the number of young banded at >2.5 wk old, but including a few nests observed to have fledged unbanded young) is further defined as a *successful* nest. Generally nest trees were not climbed until time of banding, but nests that appeared unsuccessful were checked sooner, and several nests were visited at periodic intervals from the time of hatching to fledging. At these nests wing chord measurements were taken on several young every few days to provide information on growth rate and corresponding age in days. By taking the same measurements of the young in other nests when I banded them, I was usually able to estimate hatching dates within a few days.

In 1981, a fairly typical year in terms of study effort, about 110 hr were spent searching the area and an additional 50 hr returning to check the status of nests found, band the young, and record details on nests and young. I was able to get out mostly after work and on weekends, and thus, covered only a small portion of the study area each period in the field. As with any field work, some years had more days with adverse weather or trees leafed out earlier, while in other years, conditions for conducting this type of work were better. Thus, coverage of the area varied from year to year. However, I believe that over such a long period of data collection, sampling effort fluctuated around an average which was not biased relative to the changes I observed in this RSHA population. On the other hand, I suggest that my ability to identify and include unsuccessful nests and find a greater proportion of the total population likely improved with experience.

Each year, I found or was told about RSHA nests in central Maryland outside my study area. Also, in 1975 and 1976, I spent quite a bit of time searching for nests in several nearby areas. Data for nests located outside the study area are labeled as "other nests" and included in only those analyses which would not be affected by the tendency for this subsample to include more successful nests. Collection and contaminant analysis of a small sample of eggs (Henny et al. 1973) that failed to hatch continued into the mid 1970s.

I used the linear-regression program provided by Lotus 123, Release 5, (IBM Software Group, Cambridge, MA U.S.A.) primarily to assess changes over time; levels of apparent statistical significance (Snedecor and Cochran 1980) were included to emphasize patterns and the relative magnitude of suspected changes. I also examined local Christmas Bird Count (CBC) data using linear regression. I estimated percent change over the entire period by dividing the difference between the expected values provided by linear regression for the first and last years by the value for the first year. I used 2-tailed statistical tests for this analysis.

RESULTS

Despite increasing search efforts over the years, the number of RSHA nests found in my study area has decreased substantially each 10–12-yr period (Table 1). Also, nest success has declined from the

Table 1. Summary of Red-shouldered Hawk population status and nesting performance and changes therein in central MD, 1971–2002. Other nests are those outside of the defined study area (see Study Area and Methods) in central Maryland.

Years	Location	Number of Nests Found[a]	Successful Nests		Total Young Fledged[b]	Young per		Estimated Hatching Date of Oldest Nestling		
			Number	Percent		Nest Found	Successful Nest	Earliest	Latest	Mean
Period totals and means:										
1971–80	Study area	286 + 3?	199	69.6	470	1.64	2.36			
	Other nests	40	32	80.0	76	1.90	2.38			
	All nests	326 + 3?	231	70.9	546	1.67	2.36	10 Apr	2 Jun	28 Apr
1981–90	Study area	237 + 2?	138	58.2	311	1.31	2.25			
	Other nests	51	38	74.5	98	1.92	2.58			
	All nests	288 + 2?	176	61.1	409	1.42	2.32	5 Apr	30 May	29 Apr
1991–2002	Study area	144 + 1?	69	47.9	155	1.08	2.25			
	Other nests	57	38	66.7	89	1.56	2.34			
	All nests	201 + 1?	107	53.2	244	1.21	2.28	7 Apr	23 May	26 Apr
32-yr totals and means:										
1971–2002	Study area	667 + 6?	406	60.9	936	1.40	2.31			
	Other nests	148	108	73.0	263	1.78	2.44			
	All nests	815 + 6?	514	63.1	1199[c]	1.47	2.33	5 Apr	2 Jun	28 Apr

[a] Number with question mark indicates additional nests with fate not determined.
[b] Totals do not include seven young fostered into observed nests from other areas.
[c] Of 1125 nestlings banded through 2001, 27 (2.4%) were reported later, 21 dead and six alive.

Table 2. Results of linear regression analysis of key population parameters on Red-shouldered Hawks (RSHA) in central MD.

PARAMETER REGRESSION EQUATION	TOTAL CHANGE	PROBABILITY[a]
Number of nests found in study area[b]:		
Y value for 1971–2002 = 33.0 − 0.721x	−69.3%	<0.001
Y value for 1975–2002 = 34.9 − 0.984x	−78.3%	<0.001
Number of successful nests found in study area:		
Y value for 1972–2002 = 23.5 − 0.672x	−88.2%	<0.001
Percent successful[b]:		
Y value (1971–2002) = 70.8 − 0.765x	−33.9%	0.030
Y value (1975–2002) = 68.8 − 0.823x	−32.7%	0.030
Young/nest found[b] (1971–2002) = 1.70 − 0.023x	−42.8%	0.020
Young/successful nest (1971–2002) = 2.38 − 0.009x	−11.6%	0.180
Mean hatching date (1973–2002) = 27.7 − 0.050x	−5.2%	>0.500
RSHA/party-hr from BCBC (1972–2002) = 0.16 − 0.002x	−23.1%	0.030

[a] Probability that slope (estimated change) is zero.

[b] Estimates based on all nests found may be biased because the proportion of unsuccessful nests not found was not uniform throughout the study period.

first decade of study (69.6%) relative to the most recent period of monitoring (47.9%; Table 1). Statistically significant decreases are indicated both for nests found and for nesting success (Table 2). The number of nests found in the study area decreased by 69.3% since 1971 and by 78.3% since 1975. The number of successful nests (fledging young) has decreased by 88.2% since 1972 (Table 2). Because a smaller area was studied in 1971 and my skill at finding nests, especially unsuccessful nests, likely improved for the first several years, I consider the 1972–2002 estimate (−88.2%) based only on successful nests, the best measure of the population decrease. For the same reason, the percentage of nests successful and the number of young fledged/nest found (Table 2) were likely overestimates, especially early in the study. On the other hand, young fledged *per successful nest,* which should also be relatively unbiased, has shown little long-term decrease (Tables 1 and 2). Similar results were evident among the nests found outside my study area (Table 1). Mean hatching date (28 April) may have changed slightly (to 26 April; Table 1) since about the mid 1980s, but this pattern was not statistically significant (Table 2).

DISCUSSION

Based on the difficulties of finding unsuccessful nests, as noted above (also see Johnson and Shaffer 1990), I suggest my data pertaining to successful nests are more reliable than that on total nests found, and I emphasize it here. With this subsample, there was a slightly sharper downward trend indicated in the numbers of successful nests found compared to all nests found (Table 2). Because successful RSHA nests tend to be more visible over a longer period than unsuccessful nests, they have a higher probability of being discovered by an observer than unsuccessful nests, especially those that fail early in the season. With experience, I feel I have become better at finding and identifying such unsuccessful nests and included an increasing proportion of them in my sample as the study progressed. However, nesting RSHAs often continue to occupy a territory again the following year, especially after a successful nesting season, tending to nest near the old nest site or even reuse the same nest. This makes nests in territories with a history of success easier to find year after year, and the likelihood of finding a higher portion of the successful nests thus increases as years go by. Overall, however, I believe the improvement in my ability to find unsuccessful nests had the greatest influence on my results. This more complete sample of unsuccessful nests at least partly explains the sharper decrease in young/nest found compared to young/successful nest (Table 2). However, finding more of the unsuccessful nests (and successful nests as well) should have caused total nests found in my sample to increase if the population was actually stable or increasing. Thus, as my population figures must be more complete now than in the early years of the study, the population decrease may be even steeper than my data indicate. Also, although more people become aware of this study as years go by, fewer reports of nesting hawks now come to me from other observers; another indication that the RSHA nesting population has decreased in central Maryland.

Henny et al. (1973) looked at population density and nesting success on the PWRC from 1960–71 by comparing four years with up to six RSHA nests found and five years with more than six nests located. He found that young fledged/nest was 31% lower when there were more nests, which seemed to support a density-dependent response. However, young fledged/successful nest was only 12% lower. From 1971–2002, I had 15 years (most before 1984), in which nine or more nests were found. These sites had a mean of 2.19 young fledged/successful nest and 1.12 young fledged/nest found. I had 17 years, mostly since 1983, with eight or fewer nests located, from which 2.12 young fledged/successful nest (−3%), and 1.27 young fledged/nest found (+15%). If the data back to 1960 are included, there were 25 years with fewer than nine nests found, which produced 2.15 young fledged/successful nest (−2%), and 1.32 young fledged/nest found (+18%). These data do not support the occurrence of density-dependent responses in reproductive success. However, the question of whether or not the unsuccessful nests were included in the proper proportion, especially in the early years, remains. Thus, I consider the figures based on successful nests to be the most reliable.

During the early years of this research, I assumed I was seeing normal annual fluctuations in the size and reproductive success of a relatively stable breeding population. I considered differences from year to year to be due to variations in weather conditions and other natural variables. Henny et al. (1973) concluded that rainfall had no influence on the number of young fledged/nest found. However, their figures show the difference in young/successful nest to be somewhat larger and success higher when there were 1–2 d with at least 19 mm of rain during the nesting period compared to no rain. Their study did not include any years with a longer period of heavy rain. At least short-term fluctuations in the numbers of nesting pairs and their success may be related to larger weather changes. For example, in 1995, both young

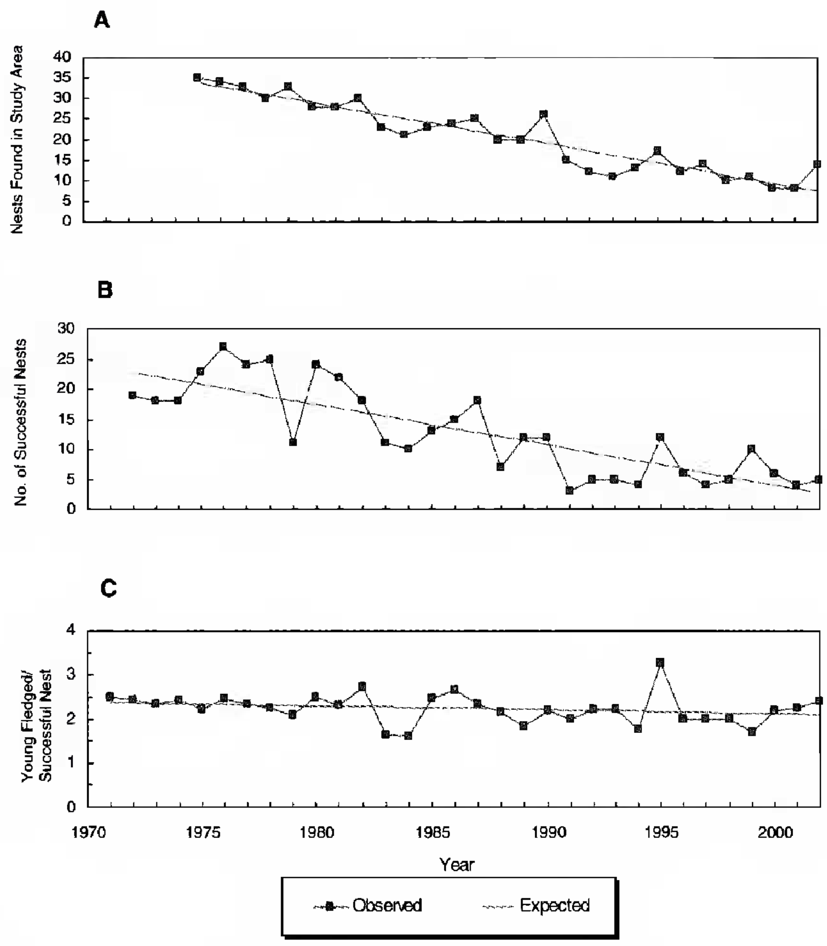

Figure 1. Trends shown in selected measurements of a Red-shouldered Hawk population in a central MD study area: (A) number of nests found from 1975–2002 (r^2 = 0.88, b = −0.98), (B) number of successful nests found from 1972–2002 (r^2 = 0.67, b = −0.67), and (C) number of young fledged/successful nest from 1971–2002 (r^2 = 0.06, b = −0.009).

fledged/successful nest (Fig. 1) and young fledged/nest found were the highest recorded in this study, an exception to the general long-term trend. This unusually successful nesting season was preceded by milder and drier than normal winter and early spring weather and followed several years of markedly colder, wetter weather with lower nesting success (Fig. 1). Generally, local weather conditions appear to me to have continued to fluctuate normally while the nesting RSHA population has declined to new lows (Table 1), a decrease which seems to have been largely independent of local weather conditions. However, changes in weather cannot be entirely ruled out. After a review of over 2000 published papers, the IPCC (Gitay et al. 2002) published an overview of the effects of climate changes, especially global warming, on biodiversity around the world. Among their findings: "There has been a discernible impact of regional climate change, particularly increases in temperature, on biological systems in the 20th century." They go on to say "Such systems include, for example . . . species distributions, and population sizes." They point out that such climate changes may impact different species in a community in different ways. For example, by putting the timing of breeding out of synchrony with the times when food is available to prepare adults for breeding or later to feed their young.

Development-related activities, particularly construction of buildings, roads, and power lines around the edges of and in the study area accompanying a growing human population, have caused a gradual deterioration in and even destruction of at least some RSHA bottomland habitat in the PWRC area as it has in many other areas (e.g., Bednarz and Dinsmore 1981, Bryant 1986). Motor-bike trails now run through the bottomland in several areas. Near Laurel in an area where "paintball wars" were conducted, I found two paintballs resting in an unsuccessful RSHA nest. Also, an expanding beaver (*Castor canadensis*) population has resulted in flooding of numerous lowland sites and the cutting and drowning of many trees and other vegetation. In addition, early in this study some logging occurred in and near the bottomland in the downstream portion of the study area. I have not attempted to measure the habitat loss, but there does not yet appear to me to be any shortage of nest sites or food for hawks in the study area, though the size and quality of many RSHA territories has likely been changed for the worse. The changes seen in the RSHA population provide the best indication of this decline in habitat. While some authors (e.g., Howell and Chapman 1997) suggest that openings such as those made by logging and beaver in woodlands benefit RSHAs, others (e.g., Bednarz and Dinsmore 1982, Moorman and Chapman 1996) found that the Red-tailed Hawk (*Buteo jamaicensis*) tended to replace RSHAs when a floodplain was opened up and fragmented. Bryant (1986), aware of widespread concerns for the status of the RSHA, studied a local population in Ontario and concluded that selective logging there had created habitat more attractive to the Red-tailed Hawk (hereafter RTHA), which forced out the RSHAs previously nesting there. I have observed increased nesting by, competition with. and predation on RSHAs in my study area by Great Horned Owls (*Bubo virginianus*) and RTHAs which now find this area better suited to their habitat requirements. The impact of Great Horned Owls was especially evident in 2000, when the remains of at least four adult RSHAs were found, three in or near their nests and a fourth in a Great Horned Owl nest. Signs of such losses have become an annual event, and I consider this as evidence that the decrease in this RSHA population was the result, both directly and indirectly, of the habitat changes observed.

While acknowledging comparison with recruitment standards (Henny 1972) that "may be slightly biased high," Henny et al. (1973) concluded tentatively that the observed recruitment rate of 1.95 fledgings/breeding pair/yr with 77% of the nesting pairs successful on the PWRC appeared to be adequate for maintaining the population. However, for most of my study, both recruitment rate and percentage of pairs nesting successfully (Table 1) have been *well below* the means reported by Henny et al. (1973). Thus, I have concluded that my study area and nearby areas contained a RSHA population that was not stable between 1971–2002, but was in fact decreasing significantly. Henny et al. (1973) also concluded that "Therefore, it is doubtful that the relatively low pesticide levels in the eggs had a detrimental effect on the reproductive performance of the population." Eggs collected in this study later in the 1970s gave results similar to those shown in Henny et al. (1973) and continue to support that conclusion.

The Bowie Christmas Bird Count (BCBC), sponsored by the local chapter of the National Audubon Society, provides additional evidence that this RSHA population has decreased (Table 2). This count, in which I have been a regular participant, began in 1972 and includes nearly all my study area and a much larger nearby area (a Christmas count circle includes almost 45770 ha), encompassing many of my other nest sites. Regression analysis indicated that the BCBC RSHA count/party-hr has decreased by 23.1% since 1972 (Table 2).

Many, if not all, of the RSHAs in my study area are year-round residents as indicated by a radiotelemetry study of local adult RSHAs in the late 1980s by M. Fuller and his assistants (Senchak 1991) and by band-recovery information. Thus, both my breeding population data and the BCBC winter population data, the latter including local young-of-the-year, likely relate to the same resident population, and both provided evidence of a population decrease. In another analysis of CBC data, McKay et al. (2002) found a substantial decrease in the RSHA population in the 1960s and no sign of recovery to former levels in a portion of the Mississippi River valley in Iowa and Illinois. An earlier study (Brown 1971) of CBC data from 1950–69, showed the RSHA population to have "decreased markedly" in a group of northern and eastern states, with a decrease of about 50% indicated for Maryland.

As discussed above, Henny et al. (1973) suggested that the nesting success of this RSHA population was density-dependent with pairs nesting closer to each other producing fewer young than pairs nesting farther apart. Thus, other factors being equal, a less dense population should have higher nesting success. However, in my study, both population density and nesting success showed decreases. In contrast, Rottenborn (2000) found both an increasing RSHA population and high nesting success in a study in California, crediting this to the unusual habitat, particularly *Eucalyptus* spp. and *Washingtonia* spp., introduced species, which increased nest site availability. Few, if any, other studies provide long-term data on both population levels and nesting success. It seems clear from my study that other factors may not be equal, that nesting success can be affected by more than just population density. Evidence of compensatory interaction between RSHA nesting success and nesting density, at least over three decades in central Maryland, appears to be lacking. On a broader scale, Henny (1972) compared mean numbers of young banded/successful nest, an estimator of young fledged/successful nest, during the periods 1900–45 (2.50 birds) and 1946–68 (2.33 birds) in a mid-Atlantic region centered on Maryland. The decrease of about 7% between these periods was not statistically significant. However, he found even larger decreases in the three other regions of the nation for which similar data were available suggesting that widespread decreases in nesting success had occurred between the early 1900s and 1968. During this period, the continental RSHA population was also believed to have undergone a widespread decline (e.g., Henny 1972, Bednarz and Dinsmore 1981). Thus, these apparent decreases in both population size and nesting success were not confined to a few scattered study areas. Again, support for the operation of density dependence and compensatory interaction appears to be lacking, at least under conditions of declining habitat quality and quantity.

RSHA populations in many other areas seem to have been decreasing at least through the 1960s. The relatively stable population apparent here until at least the early 1970s was viewed by Henny et al. (1973) as a local phenomenon—a population in an "island of remaining habitat." An analysis by Bednarz et al. (1990) suggested that the numbers of RSHA counted at Hawk Mountain, PA declined significantly between 1946–86, consistent with decreases in all five northeastern Breeding Bird Survey (BBS) strata. I do not expect the PWRC RSHA population to continue to decline in a straight line as assumed by linear regressions. Rather, I propose this population may be beginning to stabilize at a lower level as suggested by recent patterns in my data (Fig. 1).

A number of authors including Bednarz and Dinsmore (1981) and Bryant (1986) have presented evidence and argued that widespread habitat changes in recent years could be expected to produce relatively large-scale decreases in the RSHA population. This appears to have happened in my study area and in at least some other areas. However, this evidence of relatively widespread RSHA population decreases through at least the 1990s seems to be contradicted by data from the North American BBS that indicated for the period 1966–99 that the RSHA population increased in the U.S. by a mean of 2.5%/yr. This change was statistically significant, but one to be viewed with caution for a variety of sampling and biological reasons (Pardieck and Sauer 2001). Analysis for the 1966–2002 period (Sauer et al. 2003) gives a similar result at the U.S. level and indicates a 4.8% increase for Maryland (almost reaching statistical significance) for the 1972–2002 period. Could deterioration of RSHA habitats leading to lower populations have forced the remaining birds to range over larger, more open territories to survive, making them more conspicuous along BBS routes? Because of low detection rates, the BBS is likely a less perfect technique for measuring most raptor populations than it is for measuring most other bird populations. Or, as I speculate above, perhaps the RSHA population is beginning to stabilize at a relatively low level or even to recover in some areas.

More work is needed to resolve these contrary indications from different data sets. Continuation of RSHA population monitoring here together with broader studies here and elsewhere should shed further light on causes and patterns of RSHA population change. Particular attention should be given to habitat modification and destruction, but also to some perhaps less obvious threats. While the RSHA was apparently among the species relatively unaffected by DDT during or after the period of its use, 1946–72 in most areas (Bednarz et al. 1990), other environmental contaminants may be a factor. Also, the threat of West Nile virus (*Flaviviris* sp.) to the RSHA population needs to be examined.

Acknowledgments

I will not attempt to list the many people who assisted with various phases of this study from locating nests through banding nestlings as it would take much space and some would undoubtedly be overlooked; however, their help was essential and was much appreciated. I am especially indebted to C.S. Houston who kindly read several of my early annual updates on this study, provided much editorial help, and urged me to publish my data, and to G. Allen, J.C. Bednarz, C.R. Dykstra, C.S. Robbins, J.R. Sauer, and several anonymous reviewers who also provided many helpful editorial suggestions and comments on various versions of this paper.

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Received 10 December 2002; accepted 7 June 2004